RAINFALL AND CHARTS OF RAINFALL.

The great importance of the above subject, both to meteorologists and to practical engineers, has induced the editor to solicit from a number of persons some expression of their views as to the methods that should be adopted in preparing and publishing charts of rainfall. The present collection of articles began with the contribution of a short article and a chart of rainfall compiled by Mr. Henry Gannett, of the United States Geological Survey. This map was first prepared by him about 1893, and published, we believe, in the report of the census of 1890. It is now reproduced, with Mr. Gannett's latest changes, as representing the chart that has been used in connection with the work of the Division of Irrigation of the United States Geological Survey.

After carefully considering Mr. Gannett's chart, the editor decided to publish with it the newer one by Prof. A. J. Henry, of the United States Weather Bureau, in which he presents the average annual precipitation, based on thirty-one years of observations at the regular Weather Bureau stations, 1871–1901, inclusive, and on a large number of records from voluntary observers.

The relief chart that accompanies this symposium is essential to the proper study of rainfall and snowfall.

Finally, in order that our readers might have the advantage of some acquaintance with European work on this subject, and especially with the views and principles that guide in the preparation of rainfall charts, the editor submits a large number of selections from published works and recent correspondence, preceded by a few remarks of his own on points that seem to be of importance. The authors thus quoted are enumerated in the following list:

1. Henry Gannett.
2. Prof. A. J. Henry.
3. Prof. C. F. Marvin.
4. Prof. C. Abbe.
5. Prof. Julius Hann.
6. Prof. Alexander Supan.
7. Henry Gannett.
8. Henry Gannett.
9. Prof. B. E. Fernow.
10. Prof. B. E. Fernow.
11. F. H. Newell.
12. F. H. Newell.
13. Prof. George L. Goodale.
14. Prof. C. S. Sargent.
15. Prof. Julius Hann.
16. Prof. Julius Hann.
17. Prof. H. Gravelius.
18. H. Sowerby Wallis.
19. Dr. C. Hart Merriam.
20. Prof. R. F. Stupart.
21. Prof. W. H. Brewer.
22. George W. Rafter, C. E.
23. Prof. A. Woeikoff.
24. Mr. Gifford Pinchot.
25. Prof. Victor Kremser.
26. Prof. Milton Whitney.
27. Mr. Geo. E. Curtis.
28. Prof. M. W. Harrington.
29. Prof. G. Hellmann.
30. Prof. Paul Schreiber.
31. Prof. Alfred Angot.
32. Prof. A. J. Henry.
33. C. A. Schott.
34. A. Buchan.
35. A. J. Herbertson.
36. Prof. Victor Kremser.

I. THE CONSTRUCTION OF RAINFALL MAPS.

By HENRY GANNETT.

The accompanying map (XXX, No. 40), prepared five or six years ago (first edition in 1893), embodies the result of all the direct measurements of rainfall obtainable at that time. Besides these, the known effects of relief upon rainfall and the indications afforded by the streams and the character of the vegetation, so far as known, were all utilized. All direct measurements of rainfall at 1,900 stations were platted and utilized, the periods ranging from one year upward. These stations are not distributed about the country with any pretense to uniformity, but are far more abundant in the Northeastern States than elsewhere, and in most parts of the West are few in number, widely scattered, and located almost entirely in the valleys. Upon locating these stations with their records upon a large map, they were found to be extremely contradictory of one another, even when in immediate juxtaposition. Even those with records of considerable length differed from one another by large percentages. Such differences are doubtless due to local differences of environment, and it seemed that the only way to obtain a just measure of the rainfall in any considerable area would be to take the mean of a number of adjacent stations. This was done by selecting arbitrary areas, and taking the mean of all stations within each such area, giving weights to the records at the various stations in proportion to their periods of observation. The means thus obtained were assumed as the average rainfall of these areas and were thus platted, and lines sketched freely among them.

As to the rainfall in the mountains of the Cordilleran system, it is believed that the amount assigned is as a rule safely within the truth. It is altogether probable, for instance, that the high mountains of Colorado have upon their summits more than 30 inches, rather than less, although for the entire mountain area it is probably more nearly right to assume 20 to 30 inches as the amount of precipitation.

At the time this map was prepared little was known concerning the limits of different kinds of vegetation in this region, a factor which when known affords a most excellent means of sketching isohyetal lines. It is now known that the lower limit of the yellow-pine timber for nearly all parts of this region does not differ widely from the isohyetal line of 20 inches; that the lower limit of the red fir does not differ greatly from that of 30 inches; and that the best development of this species is found where the rainfall exceeds 40 inches, ranging from that up to 60 inches. The lower limit of piñons and junipers is somewhere between 10 and 20 inches, and probably nearer the former than the latter figure. Considering the fact that these limits were unknown at the time this map was prepared, excepting in a few localities, it will be seen by those who are acquainted with the matter that the isohyetal lines as drawn here conform closely in most parts of the areas to the limits of these species.

Of course in defining the limits of certain species with reference to isohyetal lines, I must not be understood as ignoring the effect of temperature as well as rainfall upon the distribution of the species. This has also a marked influence, the limitations of the different species being, as a matter of fact, set by a combination of these two elements of climate.

In conclusion, it seems to me that too much dependence is placed upon the literal records of rain gauges. After they have been located to the best possible advantage, their form improved as far as possible, and all other conditions neces-

sary for getting the best possible measurement of the annual rainfall by such method, the fact remains that this method of measuring rainfall is imperfect and uncertain, owing to a variety of circumstances.

The first and most important of these is the great range in rainfall in different years at the same station. The second, the fact that no location represents any considerable area accurately and with certainty, as is illustrated by the fact that two gauges placed within a short distance of one another often give different measurements. It seems to me, therefore, that the best way to study the distribution of the mean annual rainfall over great areas will be to measure as accurately as possible, by means of groups of stations in limited localities, the relation of precipitation to certain physical facts, and then, by means of these physical facts as observed over great areas, to extend the knowledge of the rainfall. Thus, if we were to establish stations on the west slope of the Sierra Nevada at different elevations, from the summit of the mountains to the San Joaquin and Sacramento valleys, distributing them with reference to altitude and to the limits of certain species of trees and plants, and in different latitudes from the head of the Sacramento Valley to the south end of the range, we would thus obtain the relations between the flow of streams, the altitude, the vegetation, and the rainfall. This knowledge could then be extended over the Cordilleran region as far as these related facts are known, and the rainfall could thus be predicated with a much greater degree of certainty than by any possible number of stations.

UNITED STATES
RELIEF MAP

U.S. GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

SCALE OF TINTS

- Elevation above 11000 feet
- From 8000 feet to 11000
- " 5000 " " 8000
- " 2000 " " 5000
- " 1000 " " 2000
- " 500 " " 1000
- " 100 " " 500
- " 0 " " 100
- Below Sea level

ENGRAVED BY U.S.G.S.

Scale
100 0 100 200 300 400 500 600 Miles

UNITED STATES
SHOWING
MEAN ANNUAL PRECIPITATION
BY
HENRY GANNETT

Figures indicate rainfall in inches

ENGRAVED BY U.S.G.S.

Scale
100 0 100 200 300 400 500 600 Miles